PAYLOAD CONCEPT PROPOSAL

A.T.T.A.C.K

“Attackin’ the Kraken”

Vinemont Team One

1.0 Introduction

Titan, also called Saturn VI, is the largest of Saturn's 62 moons. NASA presented the University of Alabama in Huntsville (UAH) with a mission for them to present to high school students. These students were to create a payload for conducting in-depth research on Titan, because of its resemblance to Earth. From NASA's first mission to Titan, Cassini Huygens, NASA learned of Titan's atmosphere, which is 1.5 times denser than Earth's. This atmosphere contains 98.4% nitrogen, 1.4% methane, and 0.1-0.2% hydrogen. Cassini Huygens also found lakes and winds of hydrocarbons, also Titan has a methane cycle rather than a water cycle due to the 93.7 Kelvin temperature. UAH presented Team A.T.T.A.C.K. with the reference mission along with weekly instructions to complete the mission by choosing between a set of research instruments which would be built onto Team A.T.T.A.C.K.'s unique payload design. Based on the physics, engineering, and Titan data collected from the Cassini Huygens probe, Team A.T.T.A.C.K. was to design a payload capable of completing its scientific objectives. Team A.T.T.A.C.K., which stands for Atmospheric Testing on Titan and Conditions of Kraken Mare, is the team's chosen identity. Team A.T.T.A.C.K.'s identification is derived from those of Greek mythology when Perseus, son of Zeus and Danaë, attacked and killed the Kraken. This corresponds to Lake Kraken Mare where Team A.T.T.A.C.K.'s payload will begin its journey. This lake, composed of liquid methane, is the largest of Titan's several lakes. Team A.T.T.A.C.K.'s slogan, "Attackin' the Kraken," is also based on the previously mentioned Greek myth. Team A.T.T.A.C.K.'s payload is named AK-47. It stands for Attackin' the Kraken 47 based on the team slogan and the angle of the penetrator within the payload. AK-47 is to descend into Titan's atmosphere from space aboard NASA's shuttle after a 9 to 15 year long journey and land in a lake-based lander created by UAH residing on Lake Kraken Mare, 200 kilometers off the shore of Titan. From this point, AK-47 will deploy a high altitude weather balloon to ascend through the atmosphere while undergoing research through Team A.T.T.A.C.K.'s chosen instruments. Once a decided altitude is reached above Titan's surface, AK-47 will release a penetrator to pierce the surface and measure subsurface temperatures and compare them to those of Earth.

2.0 Science Objective and Instrumentation

For Team A.T.T.A.C.K.'s science objective and instrumentation, the Titan Electromagnetic Environment Package was the chosen atmospheric testing instrument and the Balloon Slit Spectrometer was the chosen surface testing instrument. Both instruments will be located aboard the gondola of the payload continually researching while the balloon ascends. The objective of the Titan Electromagnetic Environment Package will be to test for electromagnetic fields possibly causing Titan's weather conditions in the troposphere. This is the bottom 40 kilometers of Titan's atmosphere. The Titan Electromagnetic Environment Package will also provide a high data rate resulting in more research data. Team A.T.T.A.C.K.'s surface testing instrument, the Balloon Slit Spectrometer, was chosen due to the fact that it is tuned to look for organic elements such as carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur through the use of an infrared sensor used to detect elemental composition and a camera to view what is being tested. The Balloon Slit Spectrometer also has a high data rate, a low mass, and contains two instruments, further helping Team A.T.T.A.C.K.'s decision of choice.

Table 1. Balloon Science Traceability Matrix

Science Objective	**Measurement Objective**	**Measurement Requirement**	**Instrument Selected**
Test connections with weather patterns	Measure natural and induced electromagnetic fields	Location: Top of Gondola Requirement: research only within the ascent through troposphere	Titan Electromagnetic Environment Package
Detection of organic compounds	Measure elemental composition	Location: Bottom of Gondola	Balloon Slit Spectrometer

Table 2. Penetrator Science Traceability Matrix

Science Objective	Measurement Objective	Measurement Requirement	Instrument Selected
Compare subsurface temperatures on Titan to those on earth	Measure subsurface temperatures of Titan	Location: along the length of the penetrator	Thermocouples

Table 3. Balloon Instrument Requirements

Instrument	Mass (kg)	Power (W)	Data Rate (Mbps)	Lifetime	Frequency	Duration
Electromagnetic Environment Package	0.5	3.5	3.6×10^{-6}	14.06	1 Hour	5 Seconds
Balloon Slit Spectrometer	2.5	11	2.54×10^{-6}	14.06	30 Minutes	5 Minutes

Table 4. Penetrator Instrument Requirements

Instrument	Mass (kg)	Power (W)	Data Rate (Mbps)	Lifetime	Frequency	Duration
Inertial Measurement Unit	0.013	0.22	0.16	14.06 172	Constant	Constant
On-Board Computer	0.094	0.4	N/A	14.06 172	Constant	Constant
Transmitter/Receiver	0.085	1.7	Downlink: 0.0092 Uplink: 0.0011	14.06 172	2 Hours 10 Hours	10 Seconds

Antenna	0.1	0.02	N/A	14.06	2 Hours 10 Hours	10 Seconds

3.0 Payload Design Requirements

Team A.T.T.A.C.K.'s payload requirements are to have a mass of 15 kg or less and a volume of 44 cm x 48 cm x 25 cm, be able to withstand Titan's environment, and must not cause damage to the main spacecraft. Team A.T.T.A.C.K.'s environmental requirements were to be able to withstand a temperature of -179 degrees Celsius, a surface pressure of 146.6 kPa, a g-Load of 1.352 m/s^2, a radiation that is felt from Saturn's radiation belt, chemical composition of the atmosphere being 98.4% nitrogen and 1.6% being methane and hydrogen, and ranging wind speeds consisting of hydrocarbons. For Team A.T.T.A.C.K.'s functional requirements, AK-47 must deploy with the balloon from the UAH spacecraft and provide power to take measurements from Titan, collect the data, and send the data back to UAH's spacecraft.

4.0 Analysis of Alternatives

For the Analysis of Alternatives, Team A.T.T.A.C.K. was provided with a list of alternatives for the balloon portion of the payload and the penetrator design. This is so Team A.T.T.A.C.K. could become comfortable with the physics of the mission. Also, this was used to base the design information that Team A.T.T.A.C.K. will have by the end of the project. Given 2 focus areas, Team A.T.T.A.C.K. divided the work among the design team and project manager.

For focus area #1, the objective was to determine the measurements for the balloon which consisted of neck lift, balloon size, and payload mass from the UAH-provided choices of alternatives. From the desired alternatives, Team A.T.T.A.C.K. was to calculate the burst altitude and ascent rate of the payload for each. For burst altitude, Team A.T.T.A.C.K. desired a higher altitude at which the balloon would burst because they desired to research levels of the atmosphere higher than the troposphere. For focus area #2, Team A.T.T.A.C.K. had to determine the measurements for the penetrator which consisted of penetrator mass, penetrator diameter, and starting altitude from the choice of alternatives given by the UAH. These alternatives were used to calculate the surface depth that would be reached using the penetrator. UAH wanted the penetrator to achieve a minimum penetration depth of 40 centimeters into Titan's surface.

Table 5. Focus Area #1 Results

Alternative	Neck Lift (N)	Balloon Size (g)	Payload Mass (kg)	Burst Altitude (km)	Ascent Rate (m/sec)
#1	25.35	1200	15	90-100	2.65
#2	35.49	1200	15	60-70	2.46
#3	25.35	3000	15	100-150	2.21

Table 6. Focus Area #2 Results

Alternative	Penetrator Mass (kg)	Penetrator Diameter (m)	Starting Altitude (km)	Surface Depth (m)
#1	5	0.05	70	3.97
#2	2.5	0.075	135	1.96
#3	0.75	0.125	35	0.2

5.0 Decision Analysis

For the decision analysis, Team A.T.T.A.C.K. had to weight each Figure of Merit (FOM) a 1, 3, or 9: 1 meaning of least importance, 3 of adequate importance, and 9 meaning of most importance. Team A.T.T.A.C.K. had to weight these FOMs based on whether or not they would cause mission success. For focus area #1, the importance of the balloon portion of the payload was to be decided. We classified neck lift, balloon size, and ascent rate to lower numbers. This was because Team A.T.T.A.C.K. believed as long as the balloon was ascending there was not as high level of importance for these FOMs compared to the other options. Team A.T.T.A.C.K. desired to use up all the mass allotted for the payload which would allow the team to gain as much research as possible by utilizing more space for instrumentation and batteries. Team A.T.T.A.C.K. desired a high burst altitude for the penetrator to reach the desired drop altitude and complete its portion of the mission. For focus area #2, the penetrator FOMs were to be decided. Team A.T.T.A.C.K. wanted a high mass, small diameter, and an adequate starting altitude to achieve the required surface depth, thereby completing the penetrator's mission.

Table 7. Focus Area #1 Decision Analysis

Figure of Merit	Weight	Preference	Alterative #1	Alternative #2	Alternative #3
Neck Lift	1	↔	3	9	3
Balloon Size	1	↔	9	9	3
Payload Mass	9	↑	81	81	81
Burst Altitude	9	↑	27	9	81
Ascent Rate	3	↔	27	27	9
Likelihood of Meeting Project Requirements	9	↑	81	81	81
Likelihood of Mission Success	9	↑	81	81	81

Table 8. Focus Area #2 Decision Analysis

Figure of Merit	Weight	Preference	Alterative #1	Alternative #2	Alternative #3
Penetrator Mass	9	↑	81	27	9
Penetrator Diameter	3	↔	27	9	3
Starting Altitude	3	↔	27	9	3
Surface Depth	9	↑	81	81	9
Likelihood of Meeting Project Requirements	9	↑	27	81	9
Likelihood of Mission Success	9	↑	81	81	9

6.0 Engineering Analysis

The engineering analysis required Team A.T.T.A.C.K. to begin inputting the actual engineering and design behind the payload to achieve more realistic results based on the alternative chosen during the decision analysis. For the balloon engineering analysis, Team A.T.T.A.C.K. had to calculate the total flight time of the team's balloon based on real masses and determine the mass of batteries needed to achieve the flight time. The next step was to calculate the acceleration that the balloon feels in the x-direction (or horizontally). Finally, these calculations were used to measure the distance that the balloon covers during that time to determine how the balloon should drop the penetrator over the surface. The penetrator engineering analysis was to calculate the overall time it took for the penetrator to descend. For this specific engineering analysis, Team A.T.T.A.C.K. was given the choice to either calculate the drag that the penetrator would experience while descending or refrain from including this calculation in the equation. Team A.T.T.A.C.K. decided to include drag into the equations to determine if the realistic depth the penetrator measurements chosen in the decision analysis would achieve the minimum required depth of 40 centimeters.

7.0 Final Design

The final design for team A.T.T.A.C.K.'s payload, AK-47, is to have a rectangular housing prism and a latch to allow the penetrator to drop. The 40 centimeter penetrator will be at a 47 degree angle inside of a tube that is the full length of the gondola, allowing the penetrator to slide out when the door opens. The tube keeps the instruments inside from being directly exposed to the temperature change when the door opens. The instruments will be separated by shelving underneath the penetrator and lithium-ion batteries. The outside instruments will consist of the Titan Electromagnetic Environment Package on top, the Balloon Slit Spectrometer below, and the antenna on the opposite side of the door. Team A.T.T.A.C.K. has determined all the optimum distances and lifetimes of instrumentation and total masses to achieve mission success and maximize research.

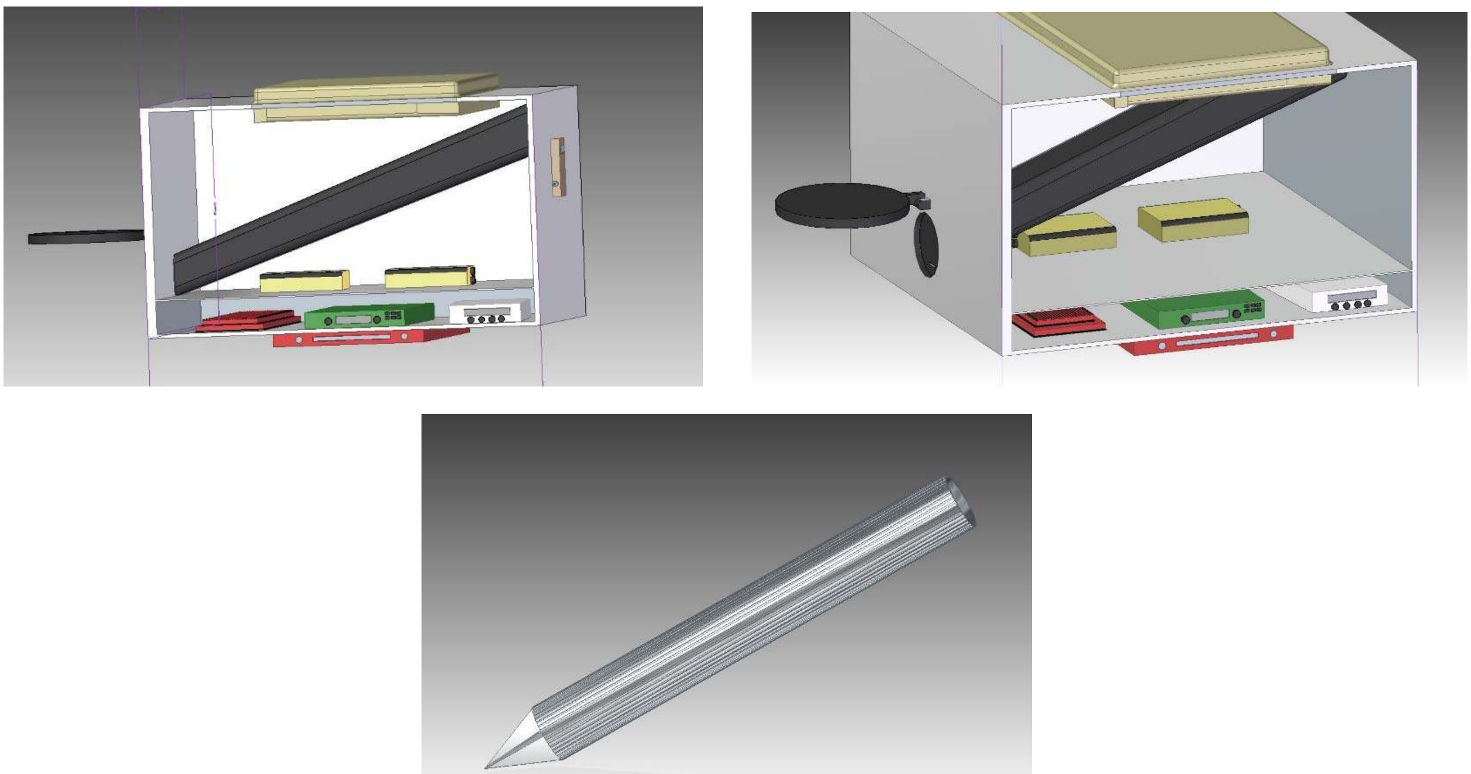

Figure 1. A.T.T.A.C.K's Mission

Table 9. Final Design Mass Table

Function	Mass (kg)
Deploy	4.00
Measure	3.65
Collect Data	0.18
Provide Power	1.36
Send Data	0.38
House/Contain Payload	4.50
Total	14.07